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(54) **MACHINING APPARATUS**

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B24B 45/00 (2006.01)

(52) **U.S. Cl.** **451/178**; 125/15; 451/360

(58) **Field of Classification Search** 451/178, 451/360, 508, 541; 125/15, 13.01, 23.01
See application file for complete search history.

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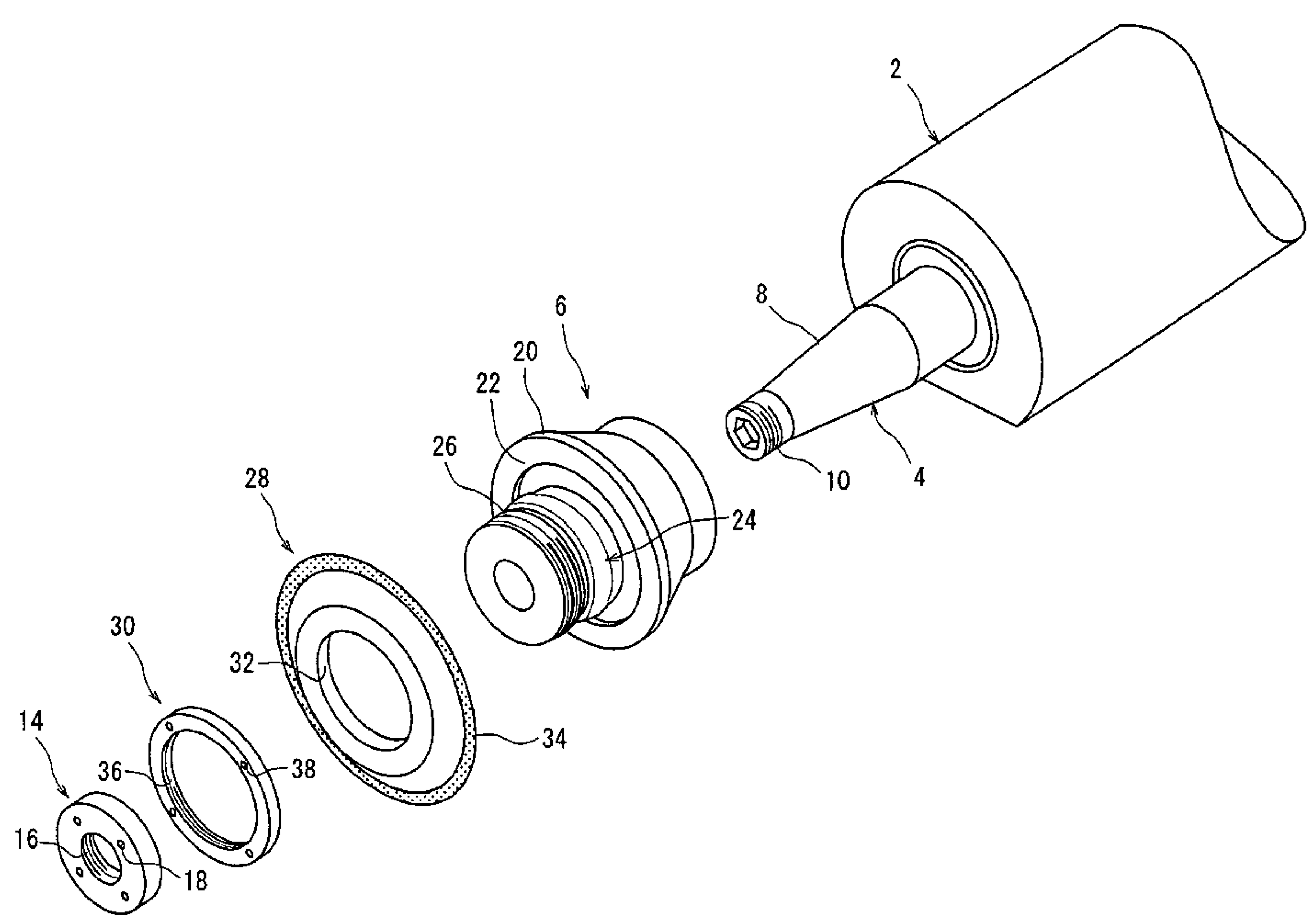
(57) **ABSTRACT**

A machining apparatus, comprising: a mounting member to be rotationally driven; a tool support member mounted on the mounting member; and a fixing member, fixed to the mounting member, for fixing the tool support member to the mounting member. The mounting member has a mounting outer peripheral surface of a generally cylindrical shape, a cylindrical mounting hole as a through-hole is formed in the tool support member, and the tool support member is mounted on the mounting member by fitting the mounting hole of the tool support member onto the mounting outer peripheral surface of the mounting member. The mounting outer peripheral surface of the mounting member has a guide region, a support region, and a relief region arranged sequentially in a central axial direction, the support region is of a cylindrical shape having an outer diameter D**1**, the outer diameter D**2** of the guide region increases up to D**1** toward the support region, and the outer diameter D**3** of the relief region progressively decreases from D**1** with increasing distance from the support region. The mounting hole of the tool support member has an inner diameter D**4**, and D**4** is larger than D**1** (D**4**>D**1**). The length in the central axial direction of the support region of the mounting outer peripheral surface is W**1**, and W**1** is $\sqrt{D4^2-D1^2}$ or smaller ($W1 \leqq \sqrt{D4^2-D1^2}$).

8 Claims, 7 Drawing Sheets



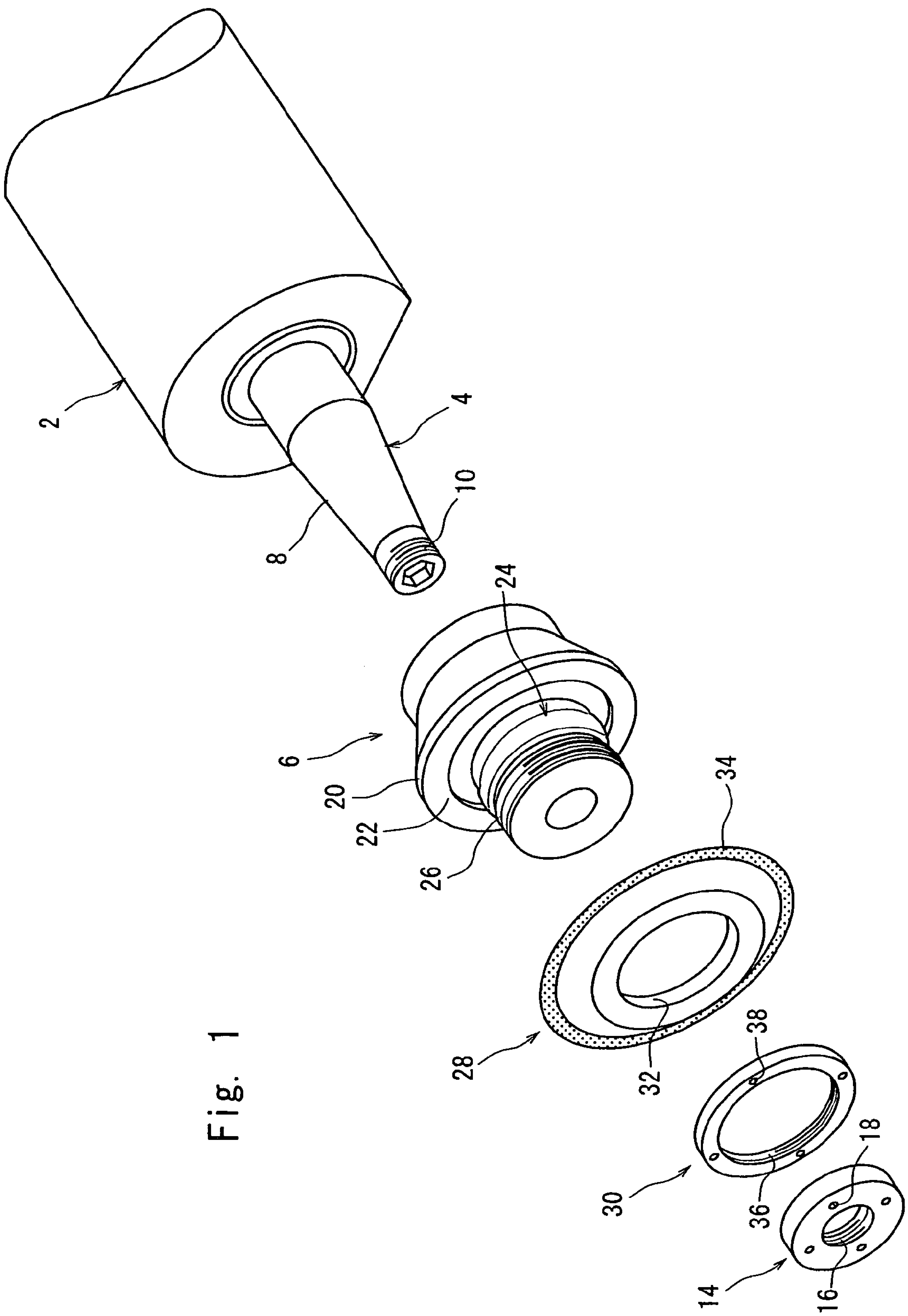


Fig. 1

Fig. 2

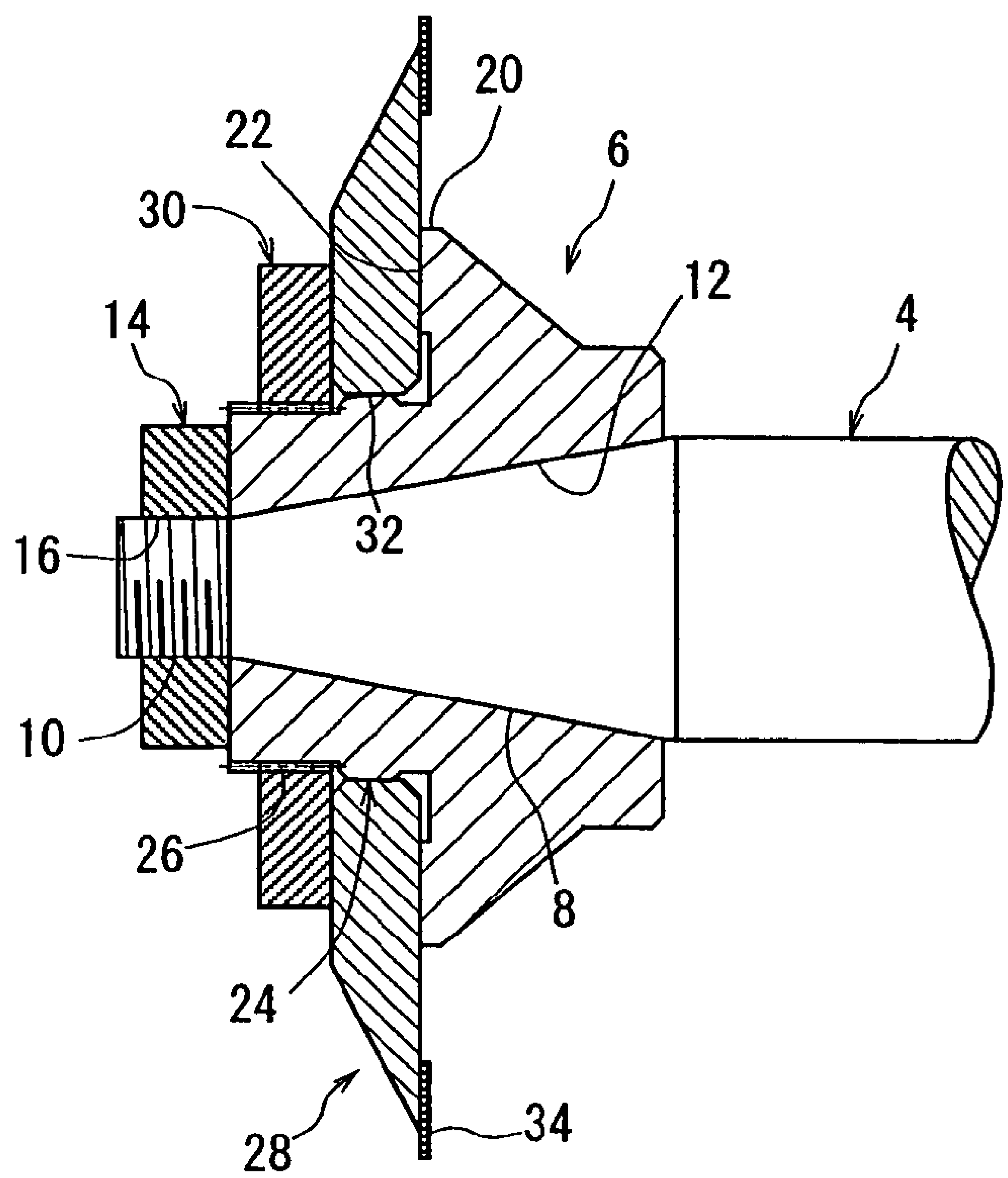

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Fig. 3

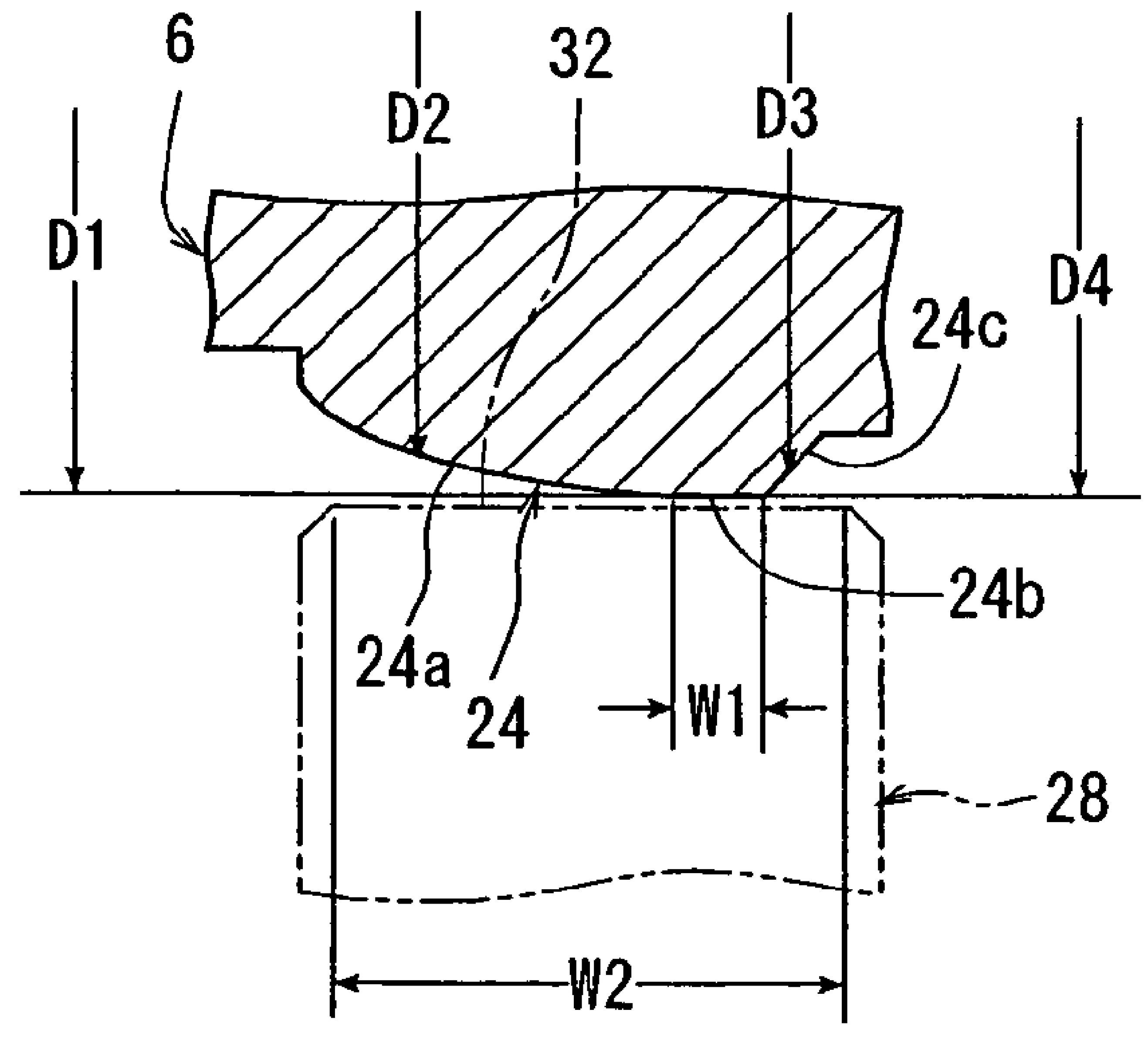
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Fig. 4

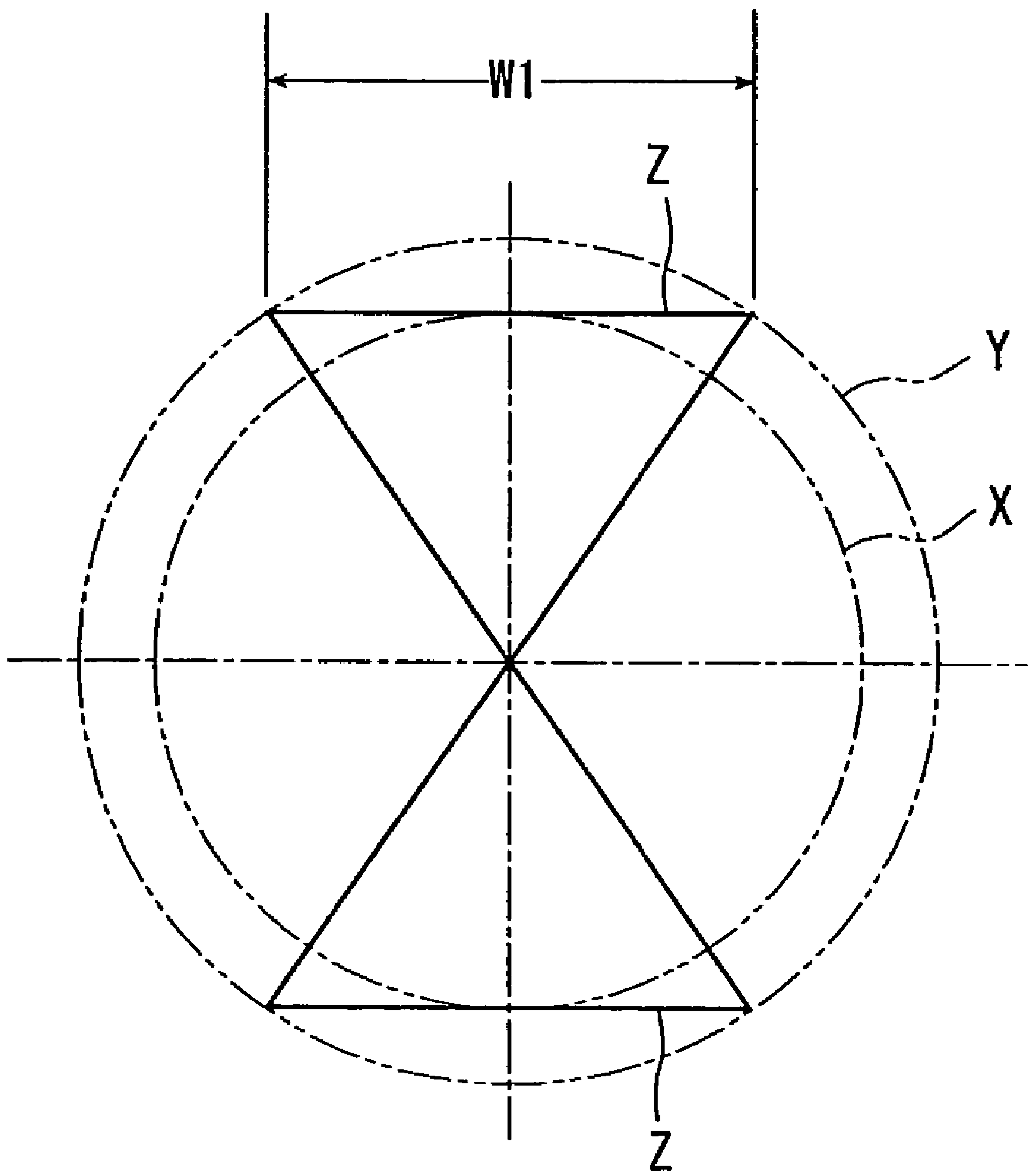


Fig. 5

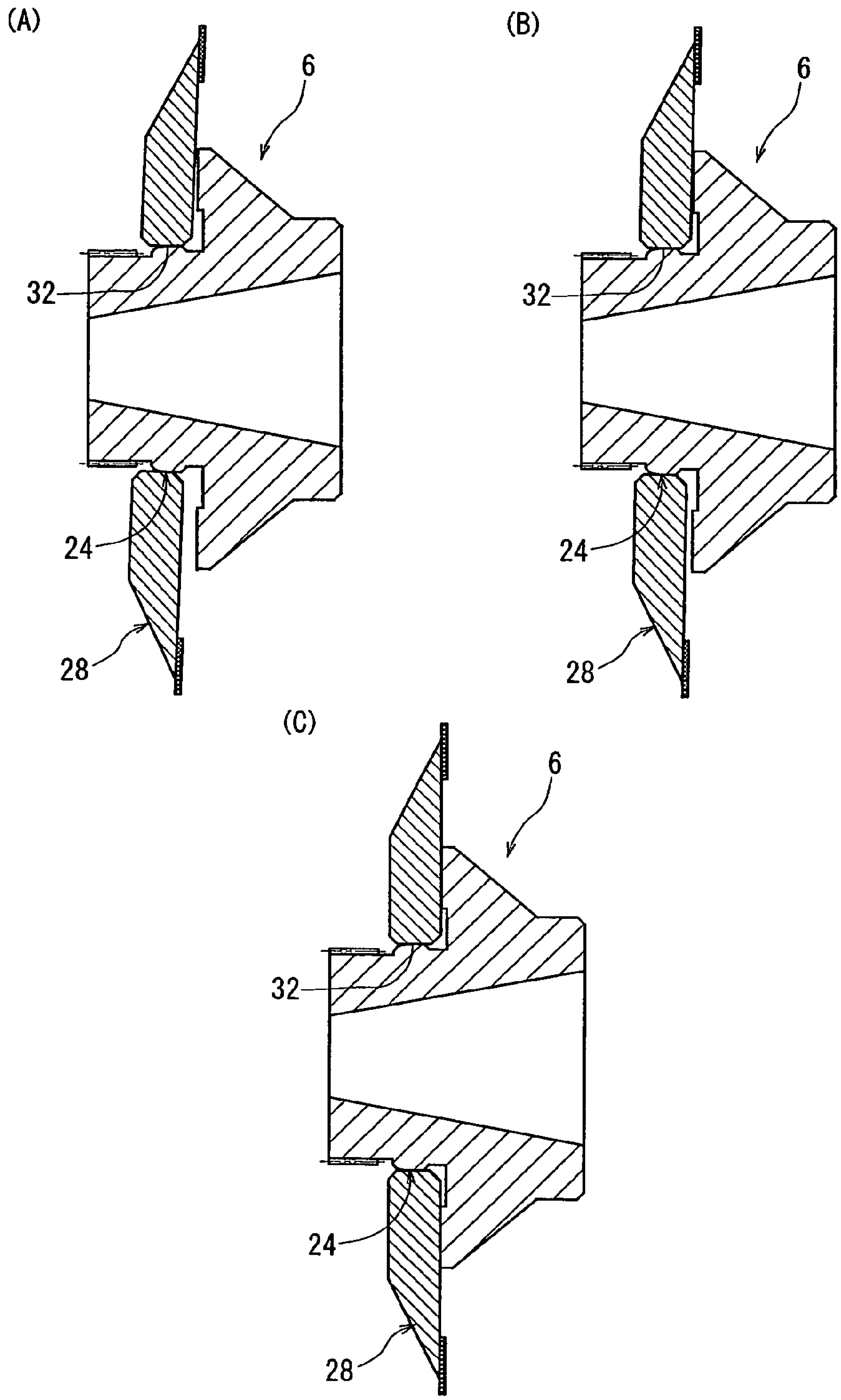
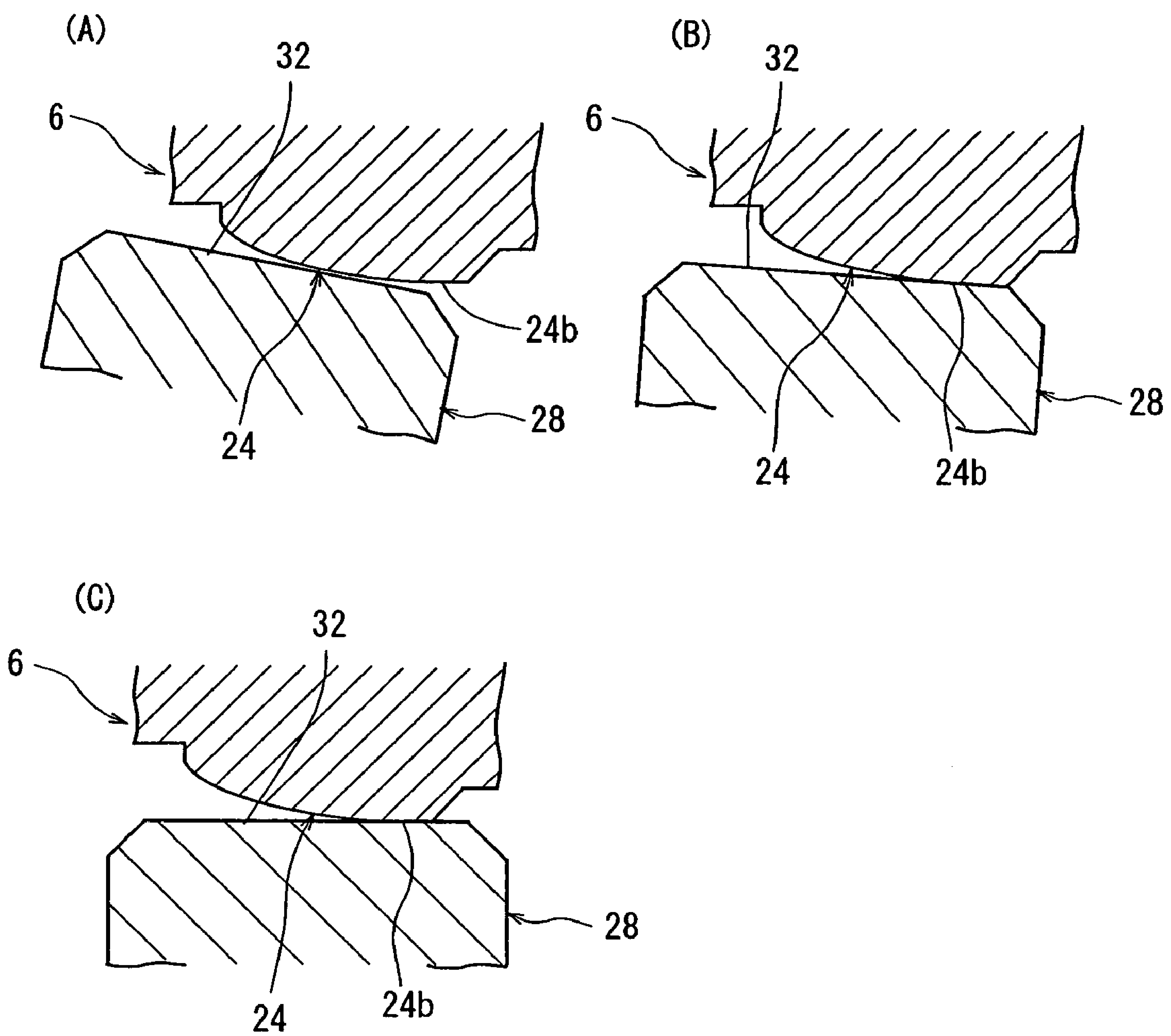


Fig. 6



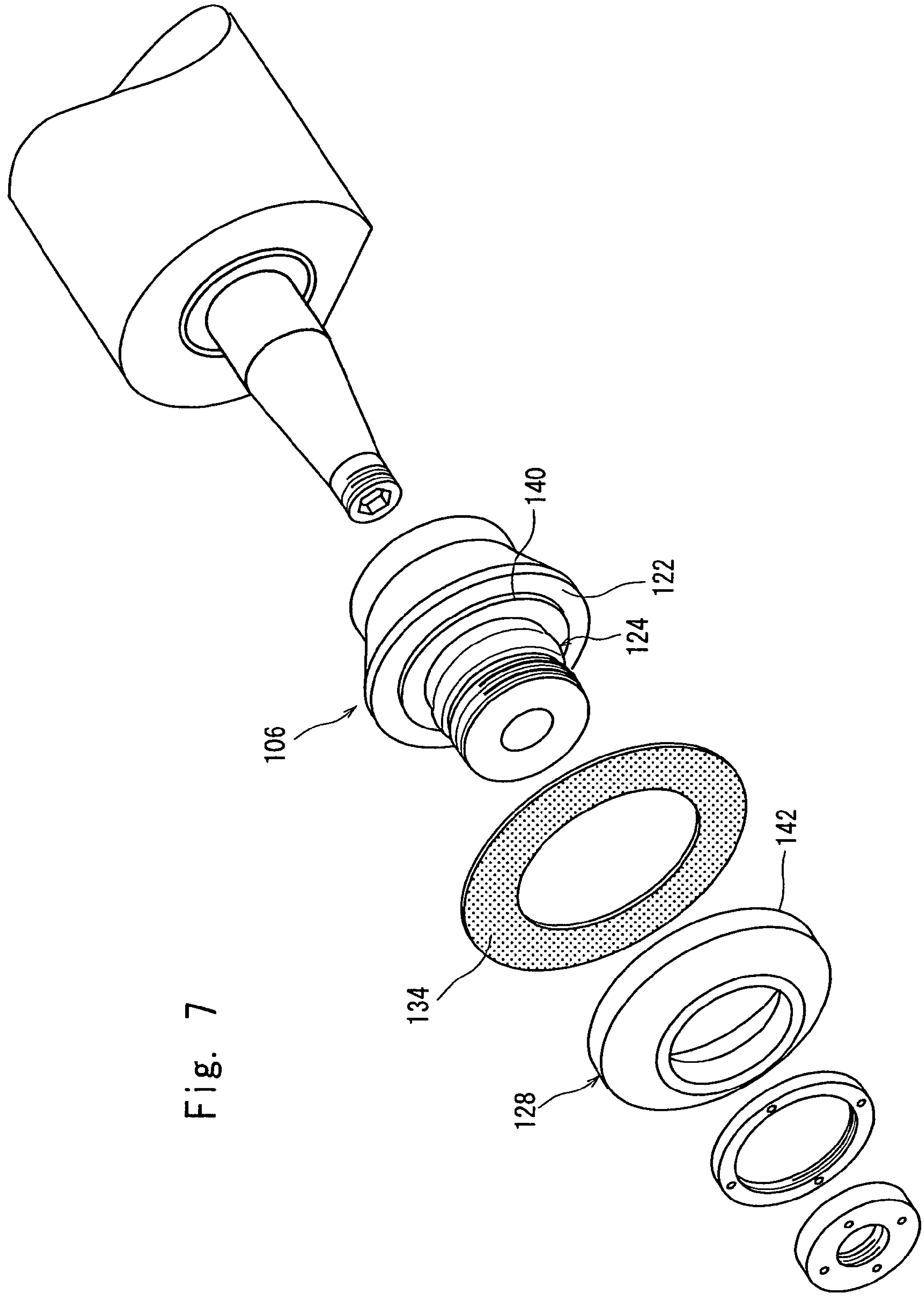
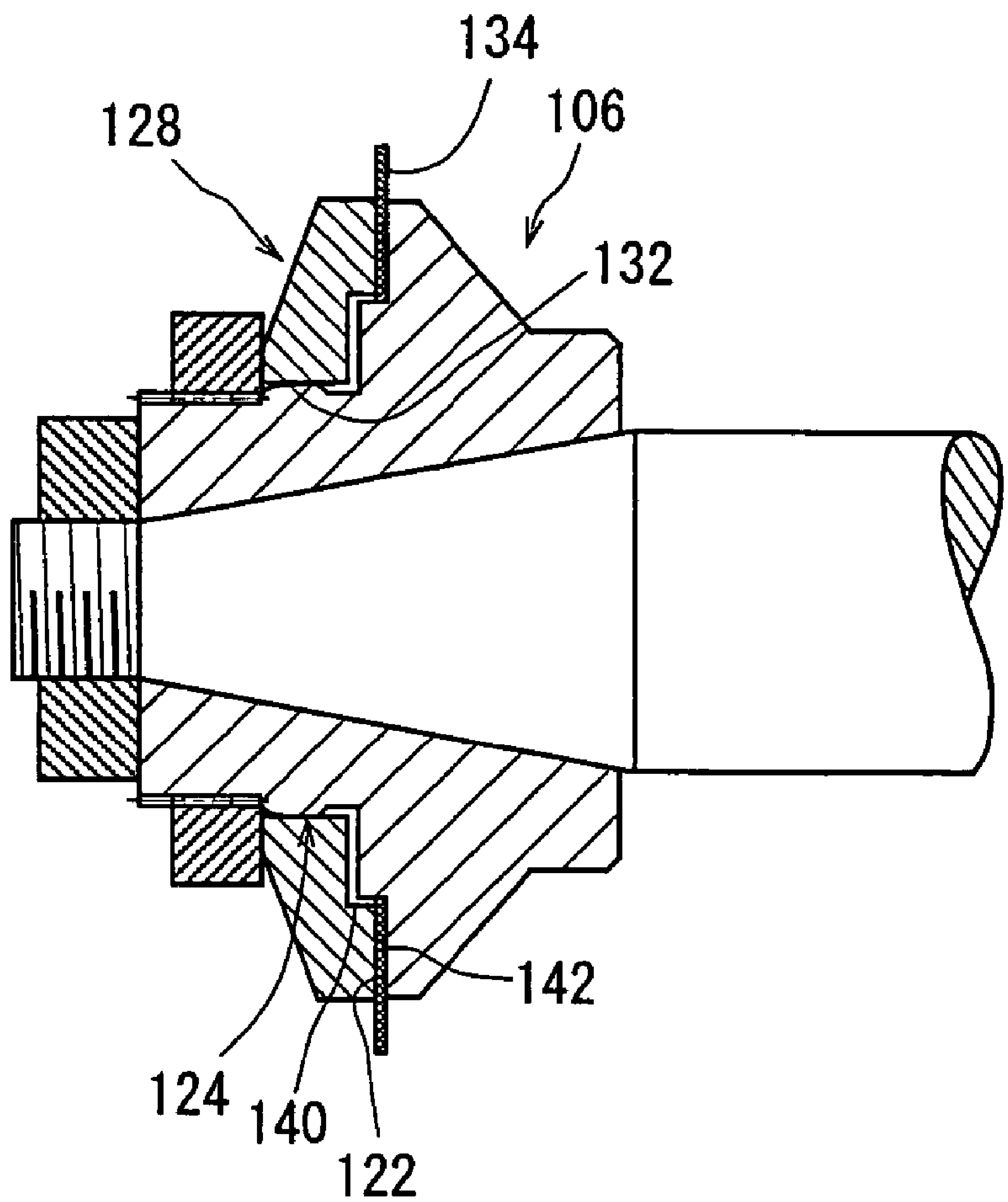


Fig. 7

Fig. 8



MACHINING APPARATUS

FIELD OF THE INVENTION

This invention relates to a machining apparatus, such as a cutting apparatus, provided with a thin-walled annular cutting blade as a machining tool. More specifically, the invention relates to a machining apparatus comprising a mounting member to be rotationally driven, a tool support member mounted on the mounting member, and a fixing member, fixed to the mounting member, for fixing the tool support member to the mounting member.

DESCRIPTION OF THE PRIOR ART

As a typical example of a precision machining apparatus equipped with a machining tool to be rotationally driven, a cutting apparatus, called a dicer, applied to the cutting of a semiconductor wafer can be named. Such a cutting apparatus has a rotating shaft mounted rotatably, and a mounting member detachably fixed to the rotating shaft, as disclosed in Japanese Patent Application Laid-Open No. 2002-219648 and Japanese Patent Application Laid-Open No. 2003-165036. A tool support member is mounted on the mounting member, and a fixing member for fixing the tool support member to the mounting member is fixed to the mounting member. In further detail, the mounting member has a mounting outer peripheral surface of a cylindrical shape, and a cylindrical mounting hole as a through-hole is formed in the tool support member. The tool support member is mounted on the mounting member by fitting the mounting hole as a through-hole onto the mounting outer peripheral surface. A through-hole having an internal thread formed thereon is formed in the fixing member, while an external thread located forwardly of the mounting outer peripheral surface is formed in the mounting member. By screwing the internal thread onto the external thread, the fixing member is fixed to the mounting member. An annular flange surface located rearwardly of the mounting outer peripheral surface is formed in the mounting member. When the fixing member is fixed to the mounting member, the tool support member is sandwiched between the annular flange surface of the mounting member and the rear surface of the fixing member, whereby the tool support member can be firmly fixed to the mounting member. A thin-walled annular cutting blade is fixed to the tool support member, or is sandwiched between the tool support member and the mounting member.

In the above-described cutting apparatus, the avoidance, if possible, of the eccentricity of the cutting blade with respect to the rotating shaft, accordingly, the eccentricity of the tool support member with respect to the mounting member, is important for precision cutting. For this purpose, the difference between the outer diameter (D**1**) of the mounting outer peripheral surface of the mounting member and the inner diameter (D**4**) of the mounting hole of the tool support member, namely, the difference (D**4**−D**1**), is set at a sufficiently small value of the order of 5 to 20 μm.

According to the inventor's experience, the above-mentioned conventional cutting apparatus has the following problems: In fitting the mounting hole of the tool support member onto the mounting outer peripheral surface of the mounting member, it is practically impossible to move the tool support member relative to the mounting member in a central axial direction, with the central axis of the mounting outer peripheral surface and the central axis of the mounting hole in complete agreement. The reality is that the tool support member is moved relative to the mounting member, with the central axis of the mounting hole being somewhat inclined with respect to the central axis of the mounting outer peripheral surface. As a result, the edge of the mounting hole tends to be pressed against the mounting outer peripheral surface during the movement of the tool support member, causing so-called drag. If the drag occurs, smooth fitting of the mounting hole onto the mounting outer peripheral surface is impeded, and damage is caused to the mounting outer peripheral surface and/or the edge of the mounting hole.

SUMMARY OF THE INVENTION

A principal object of the present invention is, therefore, to improve a machining apparatus, such as the cutting apparatus having the thin-walled annular cutting blade as the cutting tool, such that the occurrence of drag is avoided when the mounting hole of the tool support member is fitted onto the mounting outer peripheral surface of the mounting member.

The inventor diligently conducted studies, and has found that the above principal object can be attained by imparting a unique shape to the mounting outer peripheral surface of the mounting member.

According to the present invention, there is provided, as a machining apparatus for attaining the above principal object, a machining apparatus comprising a mounting member to be rotationally driven, a tool support member mounted on the mounting member, and a fixing member, fixed to the mounting member, for fixing the tool support member to the mounting member, the mounting member having a mounting outer peripheral surface of a generally cylindrical shape, and a cylindrical mounting hole as a through-hole being formed in the tool support member, and the tool support member being mounted on the mounting member by fitting the mounting hole of the tool support member onto the mounting outer peripheral surface of the mounting member, and

wherein the mounting outer peripheral surface of the mounting member has a guide region, a support region, and a relief region arranged sequentially in a central axial direction, the support region is of a cylindrical shape having an outer diameter D**1**, an outer diameter D**2** of the guide region increases up to D**1** toward the support region, an outer diameter D**3** of the relief region decreases from D**1** with increasing distance from the support region, the mounting hole of the tool support member has an inner diameter D**4**, D**4** is larger than D**1** (D**4**>D**1**), the length in the central axial direction of the support region of the mounting outer peripheral surface is W**1**, and W**1** is $\sqrt{D4^2-D1^2}$ or smaller ($W1 \leqq \sqrt{D4^2-D1^2}$).

Preferably, D**4**−D**1** is 5 to 20 μm (5 μm≦D**4**−D**1**≦20 μm), particularly 5 to 10 μm (5 μm≦D**4**−D**1**≦10 μm). Preferably, the length in the central axial direction of the mounting hole is W**2**, and W**2** is W**1** or larger (W**2**≧W**1**). Preferably, the sectional shape in the central axial direction of the guide region of the mounting outer peripheral surface is an arc, and the radius of curvature of the arc is D**1**/**2** or smaller. Advantageously, the mounting member is detachably fixed to a rotating shaft mounted rotatably, and a thin-walled annular cutting blade is fixed to the tool support member, or the thin-walled annular cutting blade is sandwiched between the mounting member and the tool support member.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an exploded perspective view showing constituent elements concerned with mounting of a cutting blade in a preferred embodiment of a machining apparatus constructed in accordance with the present invention.

FIG. **2** is an assembly sectional view of the constituent elements shown in FIG. **1**.

FIG. **3** is an enlarged sectional view showing, in an enlarged manner, some of the constituent elements shown in FIG. **1**.

FIG. **4** is a schematic view for illustrating the principle of avoiding the occurrence of drag between a mounting outer peripheral surface and a mounting hole in the constituent elements shown in FIG. **1**.

FIGS. **5**(A) to **5**(C) are sectional views showing the behaviors of a tool support member when the tool support member is mounted on a mounting member in the constituent elements shown in FIG. **1**.

FIGS. **6**(A) to **6**(C) are enlarged sectional views showing FIGS. **5**(A) to **5**(C) in a partially enlarged manner.

FIG. **7** is an exploded perspective view showing constituent elements concerned with mounting of a cutting blade in a modified embodiment of the machining apparatus constructed in accordance with the present invention.

FIG. **8** is an assembly sectional view of the constituent elements shown in FIG. **7**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred embodiments of a machining apparatus constructed in accordance with the present invention will now be described in detail with reference to the accompanying drawings.

FIGS. **1** and **2** show some of the constituent elements of a cutting apparatus as a preferred embodiment of the machining apparatus constructed in accordance with the present invention, namely, the constituent elements concerned with the mounting of a thin-walled annular cutting blade. The entire configuration of the cutting apparatus is disclosed in the aforementioned Japanese Patent Application Laid-Open No. 2002-219648 and Japanese Patent Application Laid-Open No. 2003-165036. Such disclosures are incorporated herein by reference to omit relevant descriptions.

With reference to FIGS. **1** and **2**, the illustrated cutting apparatus is provided with a casing **2**, and a rotating shaft **4** is rotatably mounted on the casing **2**. A front end portion of the rotating shaft **4** extends forward beyond the front surface of the casing **2**. A rotational drive source (not shown), which may be an electric motor, is disposed within the casing **2**, and when this rotational drive source is energized, the rotating shaft **4** is rotated at a high speed. A mounting member **6** is mounted on the front end portion of the rotating shaft **4**. In detail, a taper portion **8** of a truncated conical shape having an outer diameter progressively decreasing toward the front end is formed in the front end portion of the rotating shaft **4**. An external thread **10** is formed on the outer peripheral surface of a cylindrical portion of a relatively small diameter located nearer to the front end than the taper portion **8**. As shown clearly in FIG. **2**, a taper hole **12** of a truncated conical shape having an inner diameter progressively decreasing frontward (leftward in FIG. **2**) is formed at the center of the mounting member **6**. The taper angle of the taper portion **8** of the rotating shaft **4** and the taper angle of the taper hole **12** of the mounting member **6** are substantially the same. The taper hole **12** of the mounting member **6** is fitted over the taper portion **8** of the rotating shaft **4** to mount the mounting member **6** on the rotating shaft **4**. Then, a nut member **14** as a fixing means is screwed to the external thread **10** of the rotating shaft **4** to urge the mounting member **6** rearward (rightward in FIG. **2**), whereby the mounting member **6** is firmly fixed to the rotating shaft **4**, with the taper hole **12** of the mounting member **6** in sufficiently intimate contact with the taper portion **8** of the rotating shaft **4**. The ring-shaped nut member **14** has an internally threaded through-hole **16** formed at its center, and has four small blind holes **18** formed at intervals in the circumferential direction. In screwing the nut member **14** onto the rotating shaft **4**, tightening means (not shown) can be engaged with the small blind holes **18**. If desired, it is possible to form the rotating shaft **4** and the mounting member **6** integrally, instead of detachably fixing the mounting member **6**, which has been separately formed, to the rotating shaft **4**.

With reference to FIGS. **1** and **2**, an annular protrusion **20** protruding in the radial direction is formed in a rear portion (a right portion in FIG. **2**) of the mounting member **6**. A peripheral edge portion of the front surface (left surface in FIG. **2**) of the annular protrusion **20** is protruded somewhat forwardly, and the front surface of the peripheral edge portion defines an annular contact surface **22** substantially perpendicular to the central axis of the mounting member **6**. A mounting outer peripheral surface **24** of a generally cylindrical shape is formed in a front portion (left portion in FIG. **2**) of the mounting member **6**. The mounting outer peripheral surface **24** will be further described later in detail. An external thread **26** is formed on a cylindrical outer peripheral surface of the mounting member **6** which is located forwardly of the mounting outer peripheral surface **24**.

A tool support member **28** is mounted on the mounting member **6**, and a fixing member **30** for firmly fixing the tool support member **28** to the mounting member **6** is mounted on the mounting member **6**. The tool support member **28** in the illustrated embodiment is ring-shaped as a whole, and has a mounting hole **32** formed as a through-hole at the center thereof. With reference to FIG. **3** along with FIGS. **1** and **2**, a main portion of the mounting hole **32** is of a cylindrical shape having an inner diameter D**4** and a length W**2** in the central axial direction. The front end and the rear end of the mounting hole **32** are beveled. The rear surface of the tool support member **28** is substantially perpendicular to the central axis of the tool support member **28**, and a thin-walled annular cutting blade **34** is secured to an outer peripheral edge portion of the rear surface. An outer peripheral edge portion of the cutting blade **34** protrudes radially outwardly beyond the outer peripheral edge of the tool support member **28**. Such a cutting blade **34** is advantageously formed integrally at a required site of the tool support member **28** by electroforming well known among people skilled in the art (namely, a method in which diamond grains are dispersed in a suitable metal, such as nickel, to be electroplated on a required surface of the tool support member **28**). The fixing member **30** is composed of a ring-shaped nut member, which has an internally threaded through-hole **36** formed at its center, and has four small blind holes **38** formed at intervals in the circumferential direction.

As shown in FIG. **2**, the tool support member **28** is mounted on the mounting member **6** by having its mounting hole **32** fitted over the mounting outer peripheral surface **24** of the mounting member **6**. Then, the internally threaded hole **36** of the fixing member **30** is screwed onto the external thread **26** of the mounting member **6**, whereby the fixing member **30** is mounted on the mounting member **6**. As a result, the tool support member **28** is sandwiched between the annular contact surface **22** of the mounting member **6** and the fixing member **30**, so that the tool support member **28** is firmly fixed to the mounting member **6**. In screwing the internally threaded hole **36** of the fixing member **30** onto the external thread **26** of the mounting member **6**, tightening means (not shown) can be engaged with the small blind holes **38**.

With reference to FIG. **3** along with FIGS. **1** and **2**, it is important for the mounting outer peripheral surface **24** disposed on the mounting member **6** to have a guide region **24***a*, a support region **24***b*, and a relief region **24***c* arranged in this sequence. The support region **24***b* is of a cylindrical shape, and has an outer diameter D1 and a length W1 in the central axial direction. The outer diameter D2 of the guide region **24***a* is progressively increased up to D1 toward the support region **24***b*. In the illustrated embodiment, it is advantageous that the outer peripheral surface of the guide region **24***a*, in a sectional view taken in the central axial direction, is an arc having a center on a straight line extending substantially perpendicularly to the central axis at the boundary between the guide region **24***a* and the support region **24***b*, and the radius of curvature of the arc is D1/2 or smaller. The outer diameter D3 of the relief region **24***c* is progressively decreased with increasing distance from the support region **24***b*. The outer peripheral surface of the relief region **24***c* may be, for example, truncated conical.

It is important that the above outer diameter D1 of the support region **24***b* in the mounting outer peripheral surface **24** of the mounting member **6** is set to be slightly smaller than the inner diameter of D4 of the mounting hole **32** of the tool support member **28**. Preferably, D4−D1 is 5 to 20 μm ($5\ \mu m \leqq D4-D1 \leqq 20\ \mu m$), particularly 5 to 10 μm ($5\ \mu m \leqq D4-D1 \leqq 10\ \mu m$). It is important that the length W1 in the central axial direction of the support region **24***b* is $\sqrt{D4^2-D1^2}$ or smaller ($W1 \leqq \sqrt{D4^2-D^2}$). This feature will be described with reference to FIG. **4**. The diameter of a circle X indicated by a long dashed double-short dashed line in FIG. **4** is the same as the diameter D1 of the support region **24***b* of the mounting outer peripheral surface **24**, while the diameter of a circle Y indicated by a long dashed double-short dashed line in FIG. **4** is the same as the inner diameter D4 of the mounting hole **32**. Two straight lines Z are tangents to the circle X at two points opposed to each other in the diametrical direction. In FIG. **4**, the length of the straight line Z between two points at which the straight line Z intersects the circle Y is $\sqrt{D4^2-D1^2}$. From FIG. **4**, it is understood that if the length W1 of the straight line Z (namely, the length W1 in the central axial direction of the support region **24***b* of the mounting outer peripheral surface **24**) is $\sqrt{D4^2-D1^2}$ or smaller, the straight line Z does not interfere with the circle Y, even if the straight line Z tilts in an arbitrary direction, with the center of the circle X as the center of tilting (namely, even if the support region **24***b* tilts in an arbitrary direction relative to the tool support member **28**). Thus, it is understood that even if the mounting hole **32** tilts in an arbitrary direction relative to the mounting outer peripheral surface **24**, the inner peripheral surface of the mounting hole **32** does not cause drag to the mounting outer peripheral surface **24**. In other words, if the length W1 in the central axial direction of the support region **24***b* of the mounting outer peripheral surface **24** is $\sqrt{D4^2-D1^2}$ or smaller, drag of the edge of the mounting hole **32** of the tool support member **28** over the support region **24***b* of the mounting outer peripheral surface **24** is reliably avoided, even if the tool support member **28** is inclined when the mounting hole **32** of the tool support member **28** is fitted over the mounting outer peripheral surface **24** of the mounting member **6**. If the length of the straight line Z (namely, the length W1 in the central axial direction of the support region **24***b* of the mounting outer peripheral surface **24**) exceeds $\sqrt{D4^2-D1^2}$, the straight line Z interferes with the circle Y (that is, if the tool support member **28** tilts with respect to the support region **24***b*, the straight line Z interferes with the circle Y). Hence, drag is likely to occur between the support region **24***b* of the mounting outer peripheral surface **24** and the mounting hole **32**.

To support the tool support member **28** stably and render the strength of the support region **24***b* of the mounting outer peripheral surface **24** as high as possible, the length W1 in the central axial direction of the support region **24***b* is desired to be as large as possible. Thus, the length W1 in the central axial direction of the support region **24***b* is set, particularly advantageously, at $\sqrt{D4^2-D1^2}$ or a value slightly smaller than it. The length W2 in the central axial direction of the mounting hole **32** is preferably not smaller than the length W1 in the central axial direction of the support region **24***b* ($W2 \geqq W1$).

There may be a case where the central axis of the mounting hole **32** is somewhat inclined with respect to the central axis of the mounting outer peripheral surface **24**, as shown in FIG. **5**A or FIG. **6**A, when the mounting hole **32** of the tool support member **28** is fitted on the mounting outer peripheral surface **24** of the mounting member **6**. Even in this case, according to the machining apparatus constructed in accordance with the present invention, the occurrence of drag is reliably avoided, when the length W1 in the central axial direction of the support region **24***b* of the mounting outer peripheral surface **24** is set at $\sqrt{D4^2-D1^2}$ or smaller ($W1 \leqq \sqrt{D4^2-D1^2}$). As shown in FIG. **5**B and FIG. **6**B and FIG. **5**C and FIG. **6**C, moreover, the rear surface of the tool support member **28** is brought into contact with the annular contact surface **22** of the mounting member **6**, whereby the inclination of the tool support member **28** is corrected appropriately.

FIGS. **7** and **8** show a modified embodiment of the tool support member and the cutting blade. In the embodiment shown in FIGS. **7** and **8**, a cylindrical mounting outer peripheral surface **140** located between an annular contact surface **122** and a mounting outer peripheral surface **124** is formed in a mounting member **106**. A thin-walled annular cutting blade **134** is formed separately from a tool support member **128**, and is mounted on the mounting outer peripheral surface **140** of the mounting member **106**. In the tool support member **128**, an annular protrusion **142** protruding rearwardly is formed in an outer peripheral edge portion of the rear surface of the tool support member **128**. When the tool support member **128** is mounted, as required, on the mounting outer peripheral surface **124** of the mounting member **106**, the annular protrusion **142** of the tool support member **128** is brought into contact with the front surface of the cutting blade **134**, and the cutting blade **134** is sandwiched between the annular contact surface **122** of the mounting member **106** and the annular protrusion **142** of the tool support member **128**, whereby the cutting blade **134** is firmly fixed in place. The inner diameter of a through-hole formed at the center of the cutting blade **134** is advantageously set to be greater, by a value of the order of 5 to 20 μm, particularly, 5 to 10 μm, than the outer diameter of the cylindrical mounting outer peripheral surface **140** of the mounting member **106**. The inner diameter of the annular protrusion **142** of the tool support member **128** can be set to be somewhat larger than the outer diameter of the mounting outer peripheral surface **140** of the mounting member **106**. Advantageously, the mounting outer peripheral surface **124** of the mounting member **106** and a mounting hole **132** of the tool support member **128** are substantially the same as the mounting outer peripheral surface **24** and the mounting hole **32** in the embodiment shown in FIGS. **1** to **3**. Other features of the embodiment shown in FIGS. **7** and **8** may be substantially the same as those of the embodiment shown in FIGS. **1** to **3**, and their descriptions are omitted to avoid duplication of the descriptions.

What I claim is:

1. A machining apparatus, comprising:

a mounting member to be rotationally driven;

a tool support member mounted on the mounting member; and

a fixing member, fixed to the mounting member, for fixing the tool support member to the mounting member,

the mounting member having a mounting outer peripheral surface of a generally cylindrical shape,

a cylindrical mounting hole as a through-hole being formed in the tool support member, and

the tool support member being mounted on the mounting member by fitting the mounting hole of the tool support member onto the mounting outer peripheral surface of the mounting member, and

wherein the mounting outer peripheral surface of the mounting member has a guide region, a support region, and a relief region arranged sequentially in a central axial direction,

the support region is of a cylindrical shape having an outer diameter D**1**,

an outer diameter D**2** of the guide region increases up to D**1** toward the support region,

an outer diameter D**3** of the relief region decreases from D**1** with increasing distance from the support region,

the mounting hole of the tool support member has an inner diameter D**4**,

D**4** is larger than D**1** (D**4**>D**1**),

a length in the central axial direction of the support region of the mounting outer peripheral surface is W**1**, and

W**1** is $\sqrt{D4^2-D1^2}$ or smaller ($W1 \leqq \sqrt{D4^2-D^2}$).

2. The machining apparatus according to claim **1**, wherein D**4**−D**1** is 5 to 20 μm (5 μm≦D**4**−D**1**≦20 μm).

3. The machining apparatus according to claim **1**, wherein a length in the central axial direction of the mounting hole is W**2**, and W**2** is W**1** or larger (W**2**>W**1**).

4. The machining apparatus according to claim **1**, wherein a sectional shape in the central axial direction of the guide region of the mounting outer peripheral surface is an arc.

5. The machining apparatus according to claim **4**, wherein a radius of curvature of the arc is D**1**/**2** or smaller.

6. The machining apparatus according to claim **1**, wherein the mounting member is detachably fixed to a rotating shaft mounted rotatably.

7. The machining apparatus according to claim **1**, wherein a thin-walled annular cutting blade is fixed to the tool support member.

8. The machining apparatus according to claim **1**, wherein a thin-walled annular cutting blade is sandwiched between the mounting member and the tool support member.

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